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SCIENCE IN THE ELEMENTARY SCHOOLS.

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THIS DOCUMENT WAS DEVELOPED TO HELP ELEMENTARY SCHOOL TEACHERS KEEP PACE WITH THE CONTINUALLY ADVANCING FIELD OF EDUCATIONAL RESEARCH, PARTICULARLY AS IT APPLIES TO THE ELEMENTARY SCHOOL SCIENCE PROGRAM. IT IS ONE IN A SERIES OF PAMPHLETS ON "WHAT RESEARCH SAYS TO THE TEACHER," PRODUCED JOINTLY BY THE NATIONAL EDUCATIONAL ASSOCIATION (NEA) DEPARTMENT OF CLASSROOM TEACHERS AND THE AMERICAN EDUCATIONAL RESEARCH ASSOCIATION. A COMPLETE SUMMARY OF RESEARCH IN THE AREA IS NOT INTENDED. RATHER, THE AUTHOR HAS ATTEMPTED TO DRAW FROM RESEARCH MATERIAL ON ELEMENTARY SCHOOL SCIENCE EDUCATION THE IDEAS WHICH PROMISE TO BE MOST HELPFUL TO CLASSROOM TEACHERS. DISCUSSED ARE (1) EDUCATIONAL OBJECTIVES FOR ELEMENTARY SCHOOL SCIENCE, (2) THE DEVELOPMENT OF BEHAVIORS CONSISTENT WITH THE OBJECTIVES OF ELEMENTARY SCHOOL SCIENCE, (3) THE NATURE OF THE PROGRAM CONTENT FOR ELEMENTARY SCHOOL SCIENCE, (4) THE NATURE OF STUDENT LEARNING AS IT APPLIES TO ELEMENTARY SCHOOL SCIENCE, (5) INSTRUCTIONAL PROCEDURES AND MATERIALS, (6) THE NATURE OF SCIENCE ACTIVITIES FOR ELEMENTARY SCHOOL SCIENCE PROGRAMS, AND (7) THE EVALUATION OF LEARNING. ALL OF THE TOPICS HAVE DIRECT APPLICATION TO CURRICULUM PLANNING AND DEVELOPMENT. THIS DOCUMENT IS ALSO AVAILABLE FROM THE NATIONAL EDUCATION ASSOCIATION, PUBLICATIONS SALES, 1201 SIXTEENTH STREET, N.W., WASHINGTON, D.C. 20036. (DS)

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WHAT RESEARCH SAYS TO THE TEACHER

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Science in the Elementary Schools

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American Educational Research Association
of the National Education Association

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SCHOOLING is what happens to children and youth under the guidance of classroom teachers. Instruction is likely to be most effective when the teacher keeps his planning and instruction close to the useful and constructive findings of educational research. Through research, the modern teacher (a) seeks to maintain a sensitivity to the advancing edge of human knowledge, (b) helps to keep up on the facts that may improve his work, and (c) finds in current research stimulation toward discovering new truths from his own work and studies.

Confronted by a heavy schedule of teaching and by an overwhelming array of technical research reports, the typical teacher often must forego the benefits of research. While there is no substitute for serious study, the primary purpose of the present series of pamphlets is to indicate how research findings may help with the everyday problems of the classroom teacher. For this reason, the pamphlets are relatively brief and are written in nontechnical style.

The Department of Classroom Teachers and the AERA are indebted to the individual authors who received no honorariums and often took time that they could not readily spare. All of them have done so in the belief that research can make a difference in advancing the usefulness and quality of education.

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Science in the Elementary Schools

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EXPLANATION

The author has attempted to draw from research material on science in the elementary schools the items which promise to be of most help to classroom teachers. It is not a complete summary of research. In some instances opinion has been given which is believed to represent the views of most experts. The interpretation and recommendations are those which the author, Gerald S. Craig of Teachers College, Columbia University, believes to be soundly supported by research. His original manuscript was reviewed by Paul Blackwood, U. S. Office of Education; Julian Greenlee, Florida State University; S. Ralph Powers, University of Florida; and Robert Stollberg, San Francisco State College. Changes were made by the author on the basis of the suggestions of the reviewers and of the staffs of the AERA and the NEA Research Division.

SCIENCE IN THE ELEMENTARY SCHOOLS

Elementary science in its present form must be considered a very recent arrival in the curriculum. Looking back less than two decades, one finds science was little more than a fad and an extra-curriculum matter to be taught more or less incidentally and accidentally, if at all. Events of recent years on the national and on the international scene have convinced the public that science must be a basic concern in the curriculum of the elementary school.

THE ROLE OF ELEMENTARY SCIENCE

Analyses have been made of the nature and content of modern science, and the findings have been examined in terms of the purposes of the elementary school and of the place of science in the preservation and advancement of democracy. Studies of children, at various age levels, indicate the nature and values of their experiences in the physical environment (including both living and nonliving things).

A basic element to be considered by elementary-school teachers is that science is "interpretation." A child interprets his world. Science is man's attempt to interpret the universe. The word *interpretation* is a more satisfactory and more inclusive term for describing what goes on inside a child and within the field of science than the words *explanation* or *understanding*. Neither children nor science has final explanations or understandings of the happenings in the universe, but both children and science are involved in the active process of interpreting the physical world.

We all know that in the knowledge of science there is power, and that the world is now engaged in a great struggle which includes the ability to be resourceful with science. To fulfil their destinies, democratic peoples must be strong. Their children must be able to create and use science in the best interest of the nation and the world.

Interpretation of the physical environment must have a place in the curriculum and daily schedule. Merely talking about science will contribute little to a democracy in the international power struggle. Attempts to juggle schedules and titles of

categories or to substitute a consideration of the social significance of science for science itself will only make us unprepared for realities and perhaps lead to a loss of democratic freedoms. Interpretation of the physical environment involves the use of hands and materials as well as minds, and the realities of life demand time and space for this interpretation.

The elementary school has in its enrolment not only the future scientists of our country but also the laymen as well (and everyone is a layman outside his own field of specialization). The task of science instruction is much larger than discovering children of exceptional ability in science and starting them on their way to becoming scientists. Primarily, the task of the elementary school in science involves the education of *all* boys and girls for their own and society's benefit.

SCIENCE AND BEHAVIOR PATTERNS

For years classroom teachers have given attention to the unique contributions of science to the development of the kind of behavior essential to citizenship in a democracy. Such large behavior patterns as open-mindedness, critical-mindedness, resourcefulness, and responsibleness have rich backgrounds of content and experiences in science whether one is a child or an adult. Obviously, these great behavior patterns growing out of science are not built in a final manner in a day or a year or a decade. Development of these patterns of behavior must be a continuous program thruout the elementary school and thruout life.

Developing Critical-mindedness and Open-mindedness

As children proceed thru school, they should learn the importance of considering all the information related to important matters before drawing final conclusions.

In teaching and learning science there are many situations for the development of critical thinking on the part of both teachers and children; for instance, in explaining phenomena (events). Beginning with very young children, there are also

many opportunities to develop the ability to use tentative ideas (hypotheses). Such ideas are conveyed by children in such expressions as "It may be . . . ," and "Perhaps. . . ." The ability to consider ideas as tentative and therefore subject to revision is important to the development of a feeling of adequacy in our modern life and to the progress of democracy.

Classroom teachers can improve the thinking of children by providing guidance in the use of authentic sources, such as books, magazines, films, or television programs, developed on the level of understanding of the children. Imagination or speculation has its place in science, but teachers should help children become aware of the times when they are utilizing imagination and speculation, and the times when they are considering valid and reliable ideas.

Thru discussion, children can be encouraged to eliminate their own faulty ideas and misconceptions. At times they should be provided with illustrations of how carefully scientists work at their problems. Films, television, radio, and books developing the story of scientific discoveries may be used for this purpose.

Children need to have experiences in encountering explanations offered by other children, by the teacher, and by authentic sources which are in disagreement with their own ideas. If the disagreement involves a matter of observation, the experience can be observed again under better controlled conditions. If it involves reading, the reading material may be re-examined. Children may be able to suggest how the observations may be improved. An authentic source must be relied upon for more valid conclusions.

Developing Responsibleness

Science instruction for children can play an important part in building responsibleness since it presents a background for the development of this behavior pattern. This responsibleness can be exercised by children in their participation with the teacher in planning various science activities as related to plants, animals, school grounds, the community, excursions, or experiments. Into this planning can enter the safety of all concerned and the conservation (wise use) of materials of the environment.

At an early age children have experiences with sequences of events. A sequence may be observed in almost all kinds of phenomena, including experiments with forces and materials of everyday life such as energy, gravity, weather, simple machines, and seasons. The term *sequence of events* is preferred in this discussion to the more traditional term *cause and effect. Sequence of events* is more consistent with what both children and adults observe. It is also more consistent with the concept of *causality* as utilized in discussions of modern science.

Children can learn to think thru to consequences of behavior. Common examples are: The skates left outdoors become rusted and perhaps defective. A potted plant or a pet animal, if neglected, will no longer be healthy. A path made across the yard may become a mud puddle in a rainy period. Carelessness with a camp fire may destroy a forest.

Boys and girls are growing into situations of citizenship in which they will be responsible for keeping the air clear, the soil fertile, streams free from pollution, farms productive, the cities and country beautiful, and the world peaceful. The responsibility of citizenship is not something to be suddenly thrust upon them when they come of age. Responsibleness should be a pattern of behavior beginning in the crib. Responsibility is the birthright of every child.

Developing Resourcefulness

It is not enough for a small portion of the population to be educated as scientists, for to be truly strong an entire nation must be resourceful. The nation can be as resourceful as all people are conversant with science.

Children can be encouraged to become more resourceful thru opportunities to participate in planning in science. They can be encouraged to state possible explanations (hypotheses), to test their hypotheses, to plan experiments, to make observations, to participate in making records, and to check their ideas against authentic sources. Classroom teachers should be sure that the planning is flexible enough to utilize children's interests, ideas, and suggestions. Studies indicate that resourcefulness and

creativity increase in children when they are encouraged to participate in planning teaching-learning experiences.

The human hand combined with human intelligence has been used by mankind in the development of inventions and discoveries. The nation whose citizens can use their hands creatively is strong and resourceful. The advance of automatic machinery in our culture is providing us with more time for creativity with our hands.

Children's hands are naturally busy and contribute to their learning almost continuously. Many times children become so absorbed in constructive work, such as a toy or mechanism of their own make, as to be almost completely oblivious to their surroundings for relatively long periods of time. Creative work of this kind is to be encouraged, for out of this flows not only learning but also resourcefulness and responsibleness.

Time and space, at school and at home, are necessary for children to learn how to work safely with simple materials. Children should be encouraged to bring such constructive handwork to school and to develop leadership in an area. A teacher need not feel chagrined if certain children advance more rapidly into certain areas of science than he does. Leadership among the children may develop in areas of special interest and may be indicated by special abilities to use both hands and mind. The use of such leadership in instruction in science is a democratic way for the education of the more gifted children. Such children need to be encouraged to develop ability to communicate their individual competence in science to their classmates and the teacher.

THE CONTENT OF ELEMENTARY SCIENCE

Science instruction should be broad in scope to provide for growth in learning about all the major aspects of the environment—the sky, the atmosphere, the earth (including rocks, soils, and minerals)—conditions necessary to life, other living things, energy and forces (physical, chemical, and biological), and the inventions and discoveries of mankind. For the sake of convenience, a teacher might think of this environment of children as being all around them—the up, the down, and on the sides.

Science study interprets the universe

The environment of modern children is not restricted to the immediate neighborhood. In an age of television children are challenged not only by the ordinary things and events in their own immediate environment but also by events and processes thruout the world.

A Fundamental Core in Elementary Science

Some investigators have emphasized that there is little agreement on the subjectmatter of science in the various curriculums of public schools. They may be right when their study compares specific grade levels in various school systems. Analysis of the content of the entire span of the elementary school, however, reveals an emerging and large body of subjectmatter in science which is common to most curriculums. There is much more agreement today on the nature of elementary science than there has been at any time in the past.

Is There a Natural Sequence?

According to investigations, the response to this question depends upon how one thinks of sequence. To some workers, sequence is an absolute and rigid order of subjectmatter items for all children everywhere. In a number of earlier studies of elementary-school science, much attention was given to sequence by investigators in an attempt to determine if such an order existed. It was learned that there were many factors which made

the establishment of an absolute and universal sequence in science difficult, if not undesirable. The continuing progress of science, producing new information and new basic hypotheses, made necessary the constant revision of any preordained rigid sequence. Moreover, there were great variations among children, and, from moment to moment, in an individual child.

The sequences that have grown out of these investigations indicate a kind of "normal order," but they are flexible and should be considered as suggestive only. There are times when individual children, because of a special interest, will learn very rapidly in certain areas altho it might appear to an adult observer that the child had not secured information basic to the learning.

A given topic or problem may come up several times in a child's life, but the refinement or detail of the explanation sought by the child and provided for him by parent, teacher, or the authentic sources may differ considerably. For example, a small child may need to know that lightning is electricity. An older child may be ready for a consideration of possible causes of lightning, the nature of the discharge, and the fact that scientists are still studying lightning and have much to learn.

In another sense, however, there is a flexible sequence from a developmental point of view. For very young children there are those learnings that are based upon bodily experiences such as beginning space and time concepts, and kinesthetic and special sensory experiences which have at first no association with words. Later may come the association with words and the increasing recognition of matter and energy such as the feeling of a wind and the protective devices of certain animals. Still later may come simple interpretations with words based on direct experience and the growth of experiences in establishing abstractions such as roughness. Then follow interpretations based upon experiences, previously learned interpretations, and abstractions, including hypotheses, representing more complicated concepts.

THE GREAT PATTERNS OF THE UNIVERSE

For years we have recognized that large important principles or conceptions in science have profound influence on the think-

ing of people who gain some understanding of them. These principles are so broad and universal that they could be used as large objectives of science instruction. Recently various scientists have utilized the term *pattern* to describe such basic principles as the vastness of space; the age of the earth and the universe; and the universality of change, adaptation, interrelationship, and variation.

Since the best information scientists have at any one time must be revised in keeping with future discoveries, the content of science in the elementary school cannot be considered as set and fixed, even for a few years. Patterns, such as those listed above, seem to persist as profound descriptive principles from decade to decade in spite of the revisions and modifications that follow new discoveries.

The large patterns of the universe are being utilized as guidelines for instruction in elementary schools. A child grows or develops in his understanding and appreciation of these patterns. He begins to gain experience and learning with them while he is yet an infant. The content of science becomes more profound and meaningful to children when they are given the opportunity for continuous orientation to the basic patterns and the nature of the physical world about them.

Emphasis on Meanings

An advantage derived from the consideration of large patterns is that attention is placed upon themes and meanings (interpretations) rather than upon a mere study of objects. The modern curriculum in the elementary school contains many science themes and meanings resulting from the examination and analysis of these large patterns. This emphasis is consistent with the natural drives of children. A classroom teacher need not have ability to identify every object in the environment in order to teach themes and meanings.

Use of Events

Science is not something incidental in the lives of children. In fact, it is and probably will continue to be one of the most

dominating and decisive factors of the modern world. Schools that depend only upon incidents and objects brought to school by boys and girls will not provide them with the science education they will need for life.

On the other hand, happenings, incidents, and current events should be utilized to enrich the learning in science in a program of elementary education. Flexible planning will assist classroom teachers and children to develop the experiences needed for learning in science. Incidents and happenings in the classroom and in the community and current events in the world can be utilized without causing science to become incidental or accidental.

SCIENCE AND CONSERVATION

In addition to the development of the basic scientific principles or patterns of the universe, the classroom teacher will need to consider science as it is related to the various large aspects of conservation such as health, safety, and economy.

Developing Behavior Consistent with Health

Science in the elementary-school program provides a background for the teaching of health. In many schools health and science are integrated in the science instruction. There is general agreement that health should be more than a mere telling to children what kind of behavior is essential for individual and community health. Studies indicate that children are more likely to form good behavior patterns and health habits if they understand the background of the principles and content of science for the behavior desired.

Developing Behavior Consistent with Safety

At all levels, children need encouragement in planning for safety such as fire prevention and safety in earthquakes, tornadoes, hurricanes, electrical storms, and nuclear explosions. Children can help plan for safety on all excursions, including the short excursions even tho they may be only to the edge of the

school grounds. As children advance thru school, they acquire more of the basic information relating to forces, weather, electricity, fire, and other subjects, thus developing an intelligent basis for their own and others' safety.

What to do in case of danger must be so well discussed and practiced that safe behavior is almost automatic when such emergencies occur. All such instruction should be given in a framework of confidence and poise rather than one of fear and alarm.

We cannot fully anticipate the environments of the future for any region. Since new forms of energy and new inventions may eliminate present hazards and create new ones, it is impossible to develop a permanent code of conduct in safety instruction. Hence, emphasis must be placed upon the scientific principles essential for safety so that children can plan for their own futures. Safety education, as an aspect of conservation, can be integrated into the development of responsibility for one's own behavior and for the environment.

Developing Behavior Consistent with Economy

The relation of science to the nation's economy is illustrated in a host of problems such as the struggle with pests, soil erosion, and depletion; extinction of indigenous plants and animals; depletion of underground water supplies; maintenance of fire hazards; and pollution of air and water.

Problems cannot be solved for society thru the work of experts alone. Scientists have their functions, but citizens will either assist or retard the application of science to society's problems by their votes and behavior. In many of these problems (such as the spread of a pest), intelligent cooperation with governmental authorities is most essential. We should strive in the elementary school and in the home to build this intelligent cooperation.

Conservation as a Direction for Behavior

As children develop better understanding of the basic patterns of the universe, they also may acquire more intelligent behavior

with reference to natural resources. Conservation is a kind of behavior as well as a body of content. Courses of study should avoid encouraging undesirable kinds of behavior. An illustration of this is when children are instructed to collect living and nonliving objects from the surrounding region.

Science should teach intelligent behavior

Before removing objects, living and nonliving, from the environment and into the classroom, children and teachers may discuss many major considerations. Among them are: To whom does the object belong? Do I disturb the environment if I remove the object from it? Is the use I am going to make of the object one which merits its removal from the environment? Should I plan to return the object as soon as the study is completed? Can this object be studied properly if it is removed from the environment? If it is alive, does it have a chance to live in the classroom? Am I prepared to give it the care it needs to survive?

CHILDREN AND COMMUNITY PROBLEMS

Boys and girls are a part of the community, and the community and its environment have a tremendous influence on their development. Like all other living things, children cannot be studied properly without considering the environment in which they live. Studies indicate teachers can learn much about the community and the environment as they teach boys and girls. Since the community is so intimately integrated with the lives of boys and girls, teachers wisely increase their sensitivity to the impacts of

the community upon the attitudes, feelings, and behavior of boys and girls.

Teachers can utilize the firsthand experiences that children have had in the community by encouraging free discussion about such experiences. Studies report children as instrumental in improving some conditions such as soil erosion, disposal of refuse, and control of pests. Often these changes are a result of their own efforts in the school, on the school grounds, and in adjacent areas of the community. In such cases teachers have found it advantageous to make certain that such problems are those with which children can cope without too much frustration.

In matters involving highly controversial issues, such as those relating to the control of streams, methods of the storage of water, use of water from underground supplies, or the use of certain resources, we teachers need not take positions but rather consideration may be given to facts on both sides of the controversy. In fact, discussions on many issues are not always easily resolved with a definite conclusion; rather it is a matter of the public weighing information secured from specialists and deciding what is best for all concerned. A teacher's task is to draw the information, with the children's help, from reliable sources and to motivate and guide children toward a realization of the importance of reliable information agencies of the community. We shall need to be alert so as to detect the difference between propaganda and reliable scientific information, for propaganda is frequently given the artificial appearance of scientific fact.

Both the school and the community can provide opportunities for children to learn the value of positive action by making changes for the better. Too often school grounds are so completely landscaped as to allow children little opportunity for making improvements. Some school systems now are providing sufficient grounds for children to participate in planning and in working in garden plots, picnic areas, and outdoor pavilions for reading and study. Small areas have been left where the natural plant and animal successions of the region can be observed and studied.

Every community has an environment that is rich for study, but rich as the community may be, it is never utilized as the

sole or even the major part of the curriculum. The community is best studied in terms of the fundamental natural and social forces which have operated to make it what it is. Furthermore, the local community is but a small portion of a larger world community. The local community is subject to disturbances which may come from the outside such as a hurricane, a flood, a cold front, the purposeful or careless introduction of exotic species, the spread of contagious diseases, and the migration of living things.

A Feeling of Belongingness

Children need to develop a feeling of belonging. Belongingness may grow out of feelings which reflect such ideas as "This is my region," "This is the soil of my country," "Here is one of my country's rivers." Such feelings are of basic importance in building a behavior pattern of responsibleness.

A Feeling of Being Needed

Related to this feeling of belongingness is the feeling of being needed. It is tragic to witness boys and girls growing up with no feeling of being wanted or needed.

Intelligent and resourceful boys and girls are needed in a democracy today more than ever. This feeling of being needed is reflected in such ideas as "Here is something that someone should do," "I can do this," "I can help," "Other people need me," "The world can be improved," "All of us must plan for the safety and health of others as well as for ourselves," "There are new discoveries to be made," "There is much to learn," and "I may have a part in making new discoveries possible."

SCIENCE FROM THE DEVELOPMENTAL POINT OF VIEW

Teaching and learning in science, from the developmental point of view, can be consistent with the nature of children.

Interpretation—A Continuous Life Process

Studies reveal that children are continuously learning about their environment. This learning is broad in nature since it grows out of experiences with a wide variety of objects and phenomena. It is also fundamental in that it involves the introduction of children to the forces and materials of the universe. In a very real sense a child is developing his own identity with a physical universe.

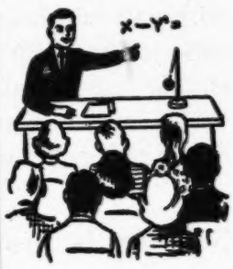
For the most part the young child may not be able to express his learning in words; nevertheless, it is real learning and very significant to his further development. Later he learns words to describe these experiences. This experimental learning has not been recognized sufficiently in science education.

This matter of interpreting the environment goes on whether there is any science instruction or not. Children seek explanations and make explanations in spite of the school. This seeking for an interpretation grows out of the demand of the child for adjustment and equilibrium. The school's task is to make certain that children are interpreting the environment and the universe in a beneficial manner. In a democracy, this means that children must be taught in an atmosphere of honesty. The procedures of science are procedures of honesty. Children growing up in a democracy have a right to the most reliable information available and to an understanding of why that information is to be considered reliable.

So science may be considered an area of child development. Just as a child changes in size and weight, he is also changing in his interpretations of the environment. If he suffers from malnutrition, he is handicapped in his physical growth; and if he is induced to accept misconceptions, superstitions, and dogmatic beliefs, his outlook on his surrounding world will be stifled. The interpretations an individual makes of his environment and the physical world are no small matter to himself or society. The environment has meaning for every individual, and the kind of meaning it possesses for him has much to do with the kind of individual he is. If he thinks his environment is filled with hostile spirits of which he is afraid, and a set of freakish principles, such as lucky or unlucky numbers, or that

human beings are doomed, he is likely to be one whose mental potentialities are stunted. If, on the other hand, the individual sees his environment as something that can be studied and intelligently utilized, he will have a more constructive outlook on life.

Science learning is developmental



The development of ideas about the environment begins in experiences in drinking, in handling objects (e.g., feeling, holding, and smelling), in crawling, in walking, and in falling, and the many other activities of babies and young children. From the developmental point of view of science education, children do not come to school for the first time at zero in science learning. They have reacted to gravity, energy, lightning, thunder, darkness, light, weather, and a host of other phenomena. They may bring with them misconceptions, superstitions, and fears and be on their way to becoming a liability to society; or they may come to school with a good attitude for learning and ready for the development of intelligent resourceful behavior. The fact a child lives in a universe of matter and energy that stimulates him to interact with it and the fact he is surrounded by other individuals with interpretations which they force upon him, cause him to form interpretations in the preschool years.

By the time a child enters the elementary school, it is quite likely that he has gained certain concepts of roughness, smoothness, lightness, speed, acceleration, pull, push, energy, stability, and many other characteristics found in the environment. He has made beginnings in an understanding of these concepts which are in reality abstractions. That is not to say he has learned

all there is to learn about these abstractions, but what he has learned, associated as these concepts are with his experiences, is most fundamental.

Both parents and teachers have contributions to make to the growth of an understanding between home and school. At all age levels, especially the nursery school and kindergarten, it is important for every child to have rich and varied experiences with natural phenomena. Simple but rugged play objects provide experiences with light, sound, heat, matter, time, space, and simple functional electricity. Experiences should be included with plants and animals, but careless and impulsive handling of living things should never be encouraged.

Science Is the Result of Human Drives

According to the developmental point of view, the origin of science lies in man's distant past. An implication of this for teachers in the elementary school is that science need not be thought of as something foreign to them or to the children they teach. Science as we know it today, with its discoveries and inventions, is the result of urges in men and women thru the ages. We see these same urges in children at home and at school.

Studies of young children reveal clearly that the interpretation of the environment is far from alien to them. From a developmental point of view of science the learning of young children about the nature of their physical universe may be profound. The universe is new to young children. They are challenged by their experiences on all sides. The universe is filled with a great variety of objects which they find intriguing. They are impressed by the events (phenomena), small and large, occurring about them. Most young children find themselves tremendously stimulated and turn naturally to exploring and learning.

Children have vivid imaginations and develop their own ideas. They indicate attempts at expectation or anticipation of events even before they have sufficient words to state these anticipations. In these anticipations of events, they show an acquaintance with sequences of events, and there seems to be developing a perception of causality.

Young children become accustomed to events occurring as a result of human activities. This may account for their asking "Who did it?" when encountering new phenomena.

A careful study of young children in their normal activities reveals a somewhat orderly and integrated learning about the physical environment. One of their remarkable abilities is to reconstruct their ideas of the physical environment and go on with their activities with little or no pause. Circumstances force them to abandon their earlier ideas and go on to new ones. Children normally are in a wholesome learning situation and in the continued process of reconstructing their ideas.

Emotions in Interpretations

Both children and adults frequently reveal emotions in learning about the physical universe. In some cases they may be subconsciously exploring their own emotional capacities.

The emotional aspects of learning in science have been neglected. Science, altho objective and realistic within itself, has emotional impacts on society and on individuals. The emotions engendered by science are not all negative. As a matter of fact, science as an activity of man has had a most wholesome effect on his emotions and his ideals, for it required man to become resourceful and responsible.

Children frequently respond with fine feeling in a discussion in science such as when considering the profound ideas of space, time, and adaptation. In stating hypotheses, children are sometimes quite exultant. There is a constructive emotion which might be expressed in a "feeling of adequacy to operate a toy, an appliance, or a situation." There may be fears of machinery, electrical storms, or of certain animals. There may be a feeling of inadequacy when a child finds himself inferior in manipulations as compared with other children. Teachers and parents need to know children's emotions in learning situations.

THE NATURE OF MODERN SCIENCE

Science has been described as the result of the drives of human beings thru the ages to make adjustment to the environment.

Unfortunately, in almost all cultures these drives have resulted at times in absolute and dogmatic interpretations of the universe which have hindered progress. Some cultures have been destroyed by the stagnation resulting from absolute points of view.

Modern science is constantly subject to revision. The more man discovers, the more he discovers that he does not know. Almost every discovery reveals vast new areas for study. Man is, as a result, creating new materials and forms of energy.

Thru science man strives for a better understanding of the world. Unfounded prejudices, opinions, gossip, rumor, astrology, myths, intuition, superstition, and all forms of dogmatic thinking cannot be considered reliable sources. Science is an active, dynamic field. So men must constantly be willing to make new observations, to repeat experiments, to consider new facts, and to challenge earlier conclusions.

Man is forced to make explanations (hypotheses) for phenomena because he does not have absolute knowledge. He uses these hypotheses only as long as they are satisfactory and abandons them whenever necessary. A young child's tendency to build expectations or anticipations as he repeats and varies earlier experiences or encounters new experiences can be compared with the scientists' development and use of hypotheses.

Stating the Source of Information

In science it is important to state the source of any comment made in explaining a phenomenon. For instance, children might say, "I read an explanation in . . . ," "My father said . . . ," "On my way to school I saw . . . ," "I have an idea," "I imagined it," or "I can do an experiment to show. . . ." This is preferable to giving such information as if the statements were unquestionable facts. Classroom teachers and children should develop a behavior pattern of identifying the source of a comment they may make in discussions in science and on all important matters.

The Scientific Attitude of Teachers

Perhaps no factor has greater potentialities for developing behavior patterns in the education of children than the behavior

that children observe in the adults with whom they are associated. Teachers and parents may teach a great deal thru their own behavior. The behavior of children frequently reflects the attitudes and behavior of parents.

The nature of modern science has many implications for a teacher and can provide him with a sense of security and adequacy in teaching children. Every teacher, on the basis of science itself, has a right to play an honest role in the classroom. He may admit he is learning, that he makes mistakes sometimes, that sometimes a child with a special interest and concentration may be learning faster than he is. In a real sense, scientific procedures are procedures of honesty, and neither teacher nor child should be penalized or humiliated for being honest.

A Revolution in Semantics

Modern science is producing a revolution in semantics which must be recognized. For instance, science with its constant revision, casts much doubt on some of the uses made of such words as *correct*, *incorrect*, and *proof* and increases the use of the words *reliable as* and *this is more reliable information*.

Modern science is profoundly influencing the role of the classroom teacher. By tradition he has been a referee, with authority to say what was correct or incorrect and to spend the teaching day in rendering decisions. Now, because of the nature of modern science, he thinks with children in determining what is the most reliable information.

TEACHING AND LEARNING SCIENCE

Teaching science is more than a presentation of the content of science as something which must be accepted by a child. Teaching is a two-way process between the educational processes and values in the mind of a teacher and the school on the one hand and the experiences and purposes of children on the other.

Children Can Participate in Planning

The classroom teacher is aware of the values toward which he would like the children to grow, beginning with their ideas

regardless of the imperfections and inaccuracies of these ideas. Growth starts where the children are. But a child also has values for every learning situation. A child's values rest in what he brings to the situation in the way of experiences, drives, challenges, and proposals.

At the beginning of a study of a problem or an area, it is well to hold an unhurried introductory session during which children can freely express their ideas without fear of humiliation. At such a session children can enter into the planning for the study.

Teachers Can Relax with Science

Teachers are wise to relax as much as possible with the children in learning situations. The rhythm and tempo of the children need to be considered in teaching and learning science. Opportunity is provided for children to react to the learning, for the learning is be thought over and to become acceptable in a real sense. Many teachers have learned the importance of providing opportunities for an idea to be tossed about in the thinking of the group, to be tested thru simple experimentation or thru observations or excursions, and to be checked against authentic sources.

Locating the Children in Their Learning

Locating where children are in their learning is to be determined in terms of the meanings they have established thru their experiences. In evaluating children's concepts, frequently too much emphasis is placed on what is wrong with their ideas. While this is important to know, it should be balanced by what they bring to the thinking that has potentialities for growth. This matter is a dynamic and positive approach to locating children in their learning and one that corresponds with the nature of children.

Frequently children express ideas which are erroneous, but in the development of the ideas they make real achievements in thinking. A teacher must make certain he does not eliminate or retard the good thinking while indicating the errors. It would

be a sounder procedure to provide children with the assistance by which they may improve their own conclusions.

Frequently a teacher fails to determine the difficulty or misconception that obstructs learning because he inhibits free expression. No child in the study of science should be penalized or humiliated for expressing an erroneous idea or for being reluctant to accept an idea. A misconception may be useful in the formulation of problems. When scolded or penalized for a statement, a child often becomes reticent, and the teacher loses one of the best means of evaluation of growth. Misconceptions need to be brought out into the open for correction thru instruction.

Science Needs No Artificial Motivation

Artificial motivation is not needed to enlist children's interest in science. If, for any reason, a teacher finds that his teaching has become dull and colorless, he has only to look to the children and to science and reverse his procedure accordingly. Both children and science are active and dynamic.

Ordinarily children will furnish the drives for the study of science, and teachers do well to use these natural drives. Children will vitalize the study of science in a way which often surprises the adult. Young children are challenged by ideas and content which seem dull and insignificant to the adult. Teachers and parents, in so far as they can, should try to view the universe thru the eyes of the children as well as thru their own.

Science has dramatic appeal to children. Frequently there is drama for them in performing experiments and in the content itself. Many teachers have found this natural interest of children a vitalization factor which saturates the science program.

A Teacher Is a Learner

Teachers are also learners in classrooms. A teacher of science, even when he is quite specialized in the subject, each semester faces the subject or problem with a new group of children who have backgrounds different from those of any children he has taught in the past. The new learning must be approached thru experiences which have meaning to children.

Critical Thinking

There are degrees of critical thinking, and there are opportunities at all levels to improve the criticalness with which one thinks. The thinking of children in the kindergarten is not so refined as the thinking of a scientist within the area of his own specialization in his own laboratory or in the field. Yet, because the thinking of young children frequently displays elements of criticalness, these elements may be reinforced, refined, improved, and given an opportunity to function in other situations under the guidance of a teacher.

In science the question, "What is the most reliable information?" is always in order. Observation, careful thinking, experiments, and other experiences may be used, provided there is a realization that in the end, the final authorities are the scientists who specialize in the particular field. The information may be obtained from authentic material for children. Authentic science books must play a vital role in the development of critical thinking.

A teacher should permit a child to bring to bear whatever personal experiences, observations, experimentation, and thinking he has to offer on the problem at hand in order that important meanings may be worked thoroly into his experiences. The attention of children when focused upon the good elements of their thinking helps them to become aware of what constitutes good thinking.

Securing the Most Reliable Information

While children do not discover new facts for mankind, they do discover new information for themselves, and this they must do day by day if they are to become adequate for the world of today and tomorrow. Fortunately, they have the assistance of the rich scientific heritage which is theirs for the taking.

If a teacher keeps in mind the kinds of challenges children recognize, he will have a natural approach to the study of science. Such questions as the following will serve to direct the procedures toward securing reliable information. How can we find out? How do we know this is reliable? Are you sure of your

facts? The procedures utilized are adapted to the level of the children so that they will know what they are doing and why they are doing it, and will have control over the process.

Too often a type of instruction consists of ferreting the answers from the children. In this procedure the teacher asks a question, expecting the children to give the response he seeks. This response is followed by another question to which another correct response is sought. Such teaching assumes an absolute concept of knowledge which is contrary to the nature of modern science.

There is more to instruction in science than eliciting pat answers to questions and problems. Attention needs to be focused upon the kind of thinking children are doing. Emphasis should be made upon how and where we may secure the most reliable information.

Using Authentic Materials

Children must learn that they cannot rely upon their own thinking alone. They learn to check their thinking with those who have specialized in the areas involved. The information in science has been produced by people who have been willing to examine anything which related to their problems. We cannot gain reliable information thru discussion alone, important as discussion is from a learning point of view. We cannot be certain of conclusions drawn from experiments or observations, significant as these experiences are. Therefore, children must learn to consult authentic materials, developed for them at their own level of comprehension. This reading plays a significant and necessary role in science instruction.

A Variety of Procedures

The classroom teacher looks to a variety of procedures and thus avoids routine methods. A change of method may bring new children into positions of leadership.

Science, with its broad fields of the environment from distant stars to the small things near at hand, demands variation in teaching procedures by the very nature of the interpretations and the fields involved. Then too, a current interest, such as a report of a

volcanic eruption, a new medical discovery, or unusual weather conditions, may influence procedures greatly in the classroom.

Developmental Procedures

Developmental teaching makes use of a variety of activities. The procedures utilized are developmental from the point of view of children and teachers, both as learners. The instruction develops, using the experiences and knowledge children have or what can be provided for them. In these developmental procedures children may participate in the development of the planning for the use of experiences, experiments, discussion, and reading to secure their learning. Children are given time to internalize new learning, integrating it with their own experiences and ideas.

Education in Science for the Slow Learner

In science teaching, the problem of slow learners may be somewhat different from what it is in other areas. In some cases retardation may be caused by difficulties in reading. On the other hand, science books have encouraged many poor readers to improve their reading abilities.

Some children require more sensory experiences for building mental pictures and abstractions than others. Many children, considered slow learners, have built up rich experiences with phenomena. It seems as if they have been having rich experiences with living and nonliving things while others have been making and using abstractions. A silent child does not always indicate a slow learner. In fact, some of our gifted workers in science and other fields have been persons who participated little in discussions.

Science in the elementary school should be taught as if it belonged to all. The slow learner will be given tasks appropriate to his abilities, including opportunities for sensory experiences with phenomena. Slow learners can also be aided in the development of abstractions by participating in discussions according to their ability and willingness.

The learning in a group will never be the same for all individuals. The teacher should not try to make it the same.

Education for Leadership in Science

Some advocate separation of the more gifted in science from others so that these superior children may advance more rapidly. They say that this would increase our supply of scientists and engineers since, on the basis of learning subjectmatter and skills, the gifted could work unencumbered by the average and retarded children.

Others feel that there is a great benefit to democracy in having future scientists and laymen in the same elementary-school classroom. They argue that children with exceptional abilities in science can be given opportunities for leadership and creative activities in the classroom and in the community without being separated from those who are less gifted.

We have already said that science offers a wide range of activities for children. Those who are gifted can take on more responsibilities for materials, charts, presentations, reports, murals, experiments, recordings, and summaries. These children often show an ability to communicate their learning to their fellows.

It is important to keep in mind that any power tool as vital as science must be in the ultimate control of all people. Science is a product of democracy and must be used as a tool of all the people.

It is not enough to make discoveries in the laboratories. In our nation machines must be operated, decisions made, repairs accomplished, and behavior at all stations of society must reflect courage, creativity, and responsibility in dealing with the resources of the nation.

TYPES OF ACTIVITIES IN SCIENCE

Discussion

Research studies indicate that discussion plays a vital part in the study of science, for it serves to clarify a problem or a phenomenon to be explained. There are opportunities for the

teacher to understand the children and for the children to understand the teacher and each other. Discussion with freedom to express ideas is a necessary part of developmental procedures.

Experiments

Every classroom of the elementary school, including the nursery school and kindergarten, is a laboratory where experimentation may be conducted. The materials can be simple and, in the main, obtained in the community. Dishes, jars, sand, soil, bottles, candles, drinking straws, magnets, dry cells, insulated wire, and seeds are illustrative of the kinds of materials which are useful in the classroom. The specialized equipment of high-school and college science has no place in the elementary school.

Individual sets of materials for each child are not necessary. An experiment, performed by members of the class and the teacher, is a cooperative enterprise.

Children should be aware of a purpose when doing an experiment and understand how the methods used in the experiment will accomplish the purpose. All children should have opportunities to make manipulations from time to time in experiments. Each child needs to have opportunity to grow in his ability to operate with materials.

During an experiment all children should be able to see what is taking place. The children doing the experiment can stand behind the table or counter, that is, on the side of the table opposite the observers. Repetition of the experiment will overcome some features missed in observing the first performance, thus giving a better experience with the special senses involved.

If possible, all materials utilized in an experiment or other instructional experience should be left in the room on a table or counter where all children may have an opportunity to get acquainted with the materials and perhaps even to perform the manipulations for themselves. Learning to think and work with materials is important in developing resourcefulness. Reading and work tables suitable for the wear and tear of science experiences for children are necessary in every classroom.

Frequently an experience is called an experiment when in reality it might be more properly classified as an experience with

a phenomenon. However, experiences with the phenomena of the environment have instructional values regardless of whether they can be classified as experiments or not. Such experiences may contribute greatly to learning.

Instructional Excursions

There are learning values when children study a phenomenon in its natural habitat. Children need an education that includes observing phenomena outside the classroom. These observations in the out-of-doors and in the community can be utilized to illustrate the themes and meanings in elementary science.

Excursions need not be lengthy either in time or distance. A successful excursion may take only a few minutes. Many interesting observations can be made at the edge of the school ground, by walking around a block, by visiting a place with a view over the landscape such as the top of a hill, a weed patch, a thicket, the school furnace room, or nearby construction work. Excursions can involve several kinds of sensory experiences such as hearing, seeing, smelling, and feeling.

An excursion should have a purpose that children accept and understand. However, there can be exploratory trips, when the purpose is exploration, from which specific purposes may evolve for later study.

Large windows of classrooms provide opportunity for observations of the seasons, weather, evidence of energy, and other phenomena. These observations can be reported and recorded thru fine arts and language arts. Frequently power lines or other community services related to science may be visible from some place on the school property.

Reading

The nature of science makes the use of science books a necessity in a classroom. Science reading material should be utilized frequently when teachers and children are studying together. Reading in science must be thoughtful reading accompanied by discussions, experiments, looking out the windows, excursions, art work, written expression, the recording of information from ob-

servations, and other activities. Continuous reading for long intervals is rare in effective science teaching.

EVALUATION OF LEARNING

Evaluation is an integral part of teaching rather than something set aside to do at a special time. As a teacher works, he can study the children to determine the effect of the learning upon them. This study of the children guides the classroom teacher as he proceeds with the instruction. He must consider whether or not the children in his classroom are developing satisfactorily toward worthy long-range purposes for the education of children.

Using a Variety of Behaviors in Evaluation

A teacher in planning his instruction is concerned in assisting children to make those changes that will secure the maximum of good for themselves and those that will cause children to develop desirable behavior.

Many forms of behavior can be utilized in evaluation. One of the most important is children's oral expression of ideas. Teachers should assist children to improve their abilities to express their ideas in science as they proceed thru the elementary school. Frequently forms of oral reporting on observations should be utilized, but we must keep in mind that some children will be superior to others in oral expression in science.

Correcting children's expression of creative ideas for grammar can result in the suppression of spontaneity. Summary periods following periods of building expectations, construction of hypotheses, and other forms of creativity can be used to develop improved language expressions.

Reporting and Recording

Art work, in which children express their understanding of phenomena, is a method frequently used to discover what conceptions and misconceptions children use. In a similar category, oral and written reporting may be considered.

It is hoped, however, that notebooks and workbooks of the variety found at the high-school and college science levels will never be introduced into the elementary school. Nothing can do more to destroy children's interest than to be required to write up experiences and learnings in routine fashion in notebooks. There is value in making decisions about information needed for later use, but the record can be kept by one or more children.

Studying Children While Teaching Science

Teachers will find their teaching enriched if they study children as they teach. Science, with its challenging content and its rich contributions to the attitudes and behavior of both adults and children, offers unique opportunities for the study of children.

In a sense it is the spontaneous behavior of children—the proposal of something to do, the inquiry, the choice of language in indicating open-mindedness, the critical-mindedness, poise, resourcefulness, the challenge of a statement, the response to a challenge, stating an hypothesis, indication of expectation, the willingness to consider new ideas, the use of old learning in new situations and learning—which is useful in evaluation.

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